Report I

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PRELIMINARY GEOLOGIC, GROUND AND SURFACE WATER DATA BACKGROUND AND PROGRESS REPORT OF KENNECOTT'S UTAH COPPER DIVISION (UCD) MINE HYDROGEOLOGIC STUDY

FOR THE UTAH GROUND-WATER TECHNICAL AND ADVISORY GROUP MEMBER REVIEW

APRIL, 1984

KENNECOTT

REPORT I.

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EXECUTIVE SUMMARY

This preliminary report is the first of five data summary progress reports to be included in the comprehensive 5.25 year ground and surface water investigation for the mine area of the Utah Copper Division (UCD), Salt Lake City, Utah.

The purpose of this report is to present to the technical and advisory group members a comprehensive document of baseline hydrogeologic, geologic, mining and water-use information needed to evaluate water quality data and potential ground-water impacts from Kennecott's mine operations.

This report includes: 1) Geologic and hydrogeologic data from Kennecott's files, 2) Partial sampling completion of and analysis of 1982 and round 1 (1983-1984) comprehensive ground and surface water quality results, 3) Discussion of the field work conducted for this report, 4) Published hydrologic and hydrogeologic data from state and federal agencies, 5) Preliminary conclusions, and 6) Recommendations on future sampling and new monitor well completions. This report reflects the work effort of Kennecott and the technical and advisory groups over the first nine months of this 5.25 year study. Dames & Moore and Intera, Kennecott's consultants, reviewed this report prior to submittal of this final draft to the technical and advisory group members. Both consultants have copies of this final draft for their final review and comments.

Only one round of comprehensive ground and surface water quality data were obtained in 1983-1984 and are included in this report along with 1982 data. Most of the private irrigation wells could not be sampled since the owners only pump these wells in the spring or summer months. These wells will be sampled by Kennecott in 1984, if and when they are pumped by the owners. Consequently, any conclusions based on the limited data presented must be viewed as preliminary subject to change, as the historical water quality data are evaluated in detail, as round 2 and subsequent water quality data are obtained and evaluated and as additional hydrogeologic data, obtained from new monitor well construction and testing, are available.

Hydrogeologic data obtained as new monitor wells are completed (in 1985) and sampled are critical to understanding the shallow and deep ground-water flow systems in the study area. Water level and water quality data from these new monitor wells will reflect hydrogeologic conditions in the zones of critical interest and importance (i.e. the upper shallow aquifer and the deeper confined aquifer and the zones therein).

PRELIMINARY CONCLUSIONS

This preliminary investigation indicates that there are two and possibly three aquifer flow systems in the study region. A shallow unconfined aquifer, a deep confined (principal) aquifer and possibly shallow perched aquifers are present. The shallow and deep aquifers may be interconnected in the area along the foothills of the Oquirrh Mountains, but are separated by clay/silt lenses and layers in the valley. All three aquifers consist primarily of Quaternary age gravels and lake bed deposits. ?

Existing hydrogeologic and water quality data indicate that the upper shallow aquifer (located near Kennecott's leach dumps, the Bingham reservoirs, both the 500 million gallon and 20 million gallon, the evaporation ponds and along Bingham Creek (approximately two miles east of Copperton)) has been affected by Kennecott and pre-Kennecott mining operations.

Historic and current water quality data from deep wells which penetrate and appear to reflect conditions in the deeper confined (principal) aquifer in these areas do not indicate significant water quality degradation in the deep aquifer. The deep aquifer is generally of high yield with TDS and sulfate levels slightly above drinking water standards.

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In this western part of Salt Lake Valley, groundwater is used principally for industrial and irrigation purposes. Water quality data obtained from 1) the Copperton production wells located two miles north of the Bingham Reservoirs, 2) Kennecott's production well located approximately two miles east of the Bingham Reservoirs, 3) Riverton City's production wells located approximately seven miles southeast of the Bingham Reservoirs, and 4) numerous private wells located south, north and east of Kennecott's facilities, indicate that the water quality in these private wells has not been impacted by Kennecott.

Limited review of the historical water quality data suggest that pH, sulfate and metals contaminant distributions have not changed significantly since 1975. Migration of contaminants, (the primary one being sulfate), to the north, south and east will likely continue but at a slow rate as they have historically done. Detailed evaluation of the historic water quality data and trends will be completed in August, 1984 for the draft environmental impact statement (EIS).

Valid conclusions concerning contaminant migration rates and migration paths cannot be made until all of the existing hydrogeologic data are evaluated, in detail, and additional water quality and hydrogeologic data from private irrigation wells and Kennecott's new monitor wells are available.

Recommendations on future water quality sampling and new monitor well specifications are included in this preliminary report. These recommendations are subject to review and approval by the technical and advisory groups.

REPORT I. PRELIMINARY GEOLOGIC, GROUND AND SURFACE WATER DATA BACKGROUND AND PROGRESS REPORT OF KENNECOTT'S UTAH COPPER DIVISION (UCD) MINE HYDROGEOLOGIC STUDY FOR THE UTAH GROUND-WATER TECHNICAL AND ADVISORY GROUP MEMBER REVIEW, APRIL, 1984.

INTRODUCTION

Kennecott operates a large open pit copper mine in Bingham Canyon. The pit covers 1900 acres, is over 2.3 miles wide at the top in an east-west direction and it is over .5 mile deep from top to bottom. Kennecott leaches waste dumps and runs concentrating, smelting and refining complexes located south and west of Salt Lake City, Utah, respectively. The mine, overburden dumps, and leach operations are located approximately 20 miles southwest of Salt Lake City (Figure 1). The concentrators, smelter and refinery are located approximately 15 miles west of Salt Lake City. Tailings from the concentrators are disposed of in the existing tailings pond located north and west of the town of Magna. Mine waste is disposed of and leached in a closed leach recovery circuit. The waste is dumped directly east of the Bingham Pit along the foothills of the Oquirrh Mountains. The dumps cover a 4.5 mile north-south area that extends south from the town of Copperton. Locations of the Kennecott mine facilities and general physiographic features in the study area are shown on Figures 2, 3, and 4.

Does Kennecott own Kennecott [illegible]?

Kennecott's mining operations, ongoing since 1936, and other non-Kennecott mining operations, ongoing since 1865, have impacted the ground and surface waters within and downgradient of the Bingham Canyon Mining District. To better assess the impacts of Kennecott's mining operations on the ground and surface waters, Kennecott is evaluating historic water quality data and has upgraded the existing ground and surface water quality sampling and monitoring systems. The first task of the 5.25 year comprehensive hydrogeologic study at Utah Copper Division (UCD) was completed with the assistance of Intera Technologies, Inc., Dames & Moore Consulting Engineers, and the technical and advisory groups. The technical group consists of scientists from the state and county who have reviewed data and consulted with Kennecott throughout this project. The technical group has met with Kennecott staff six times in 1983-1984, prior to completion of this draft report. The data, preliminary conclusions and recommendations presented in this report complete a portion of Task 1. Thorough evaluation of historic water quality data and trends and evaluation of all of round 1 data will be completed in August, 1984 for the draft (EIS).

This report presents preliminary evaluations of: 1) the hydrogeology and hydrology of the Bingham Canyon Mining District and surrounding area, 2) the potential impacts of Kennecott's mining operations on the surrounding ground and surface waters, and 3) recommendations and proposed construction and locations of new monitor wells.

Published and unpublished hydrologic and hydrogeologic data from Kennecott's files are included in this report. The data and preliminary data evaluations are primarily limited to the area shown on Figure 2. Discussion of the regional geology and hydrology, however, includes the entire Jordan River Basin.

MINING HISTORY OF THE STUDY AREA

The following summary of the mining history in the Bingham Canyon area is from Hammond, E.D. (1961), James, A. and others (1961) and the Society of Economic Geologists (1975). A knowledge of the mining history is very important in understanding the magnitude of the naturally occurring metals (lead-zinc-silver-gold, copper and molybdenum) potential movement of such metals with ground-water recharge and flow and the extensive duration of pre-Kennecott mining activities in the Bingham Canyon District (Figures 5 through 7).

The first mining claim in Bingham Canyon was a lead ore deposit named the "Jordan," established in 1863. The "West Mountain Mining District" was established at the same time and included an area from the Jordan River on the east to the Oquirrh Range Divide on the west. The original mining claim was patented in 1877, was the longest in the country and extended for 52,000 feet.

Placer gold mining became active by 1865 and approximately $1,000,000 in gold was recovered from the Bingham Canyon gravels by 1871.

Construction of the Bingham Canyon railroad by the Bingham Canyon and Camp Floyd Railroad Companies in 1872 renewed the exploitation of the lead-silver deposits from the Jordan, Galena, Neptune, Yosemite, Kempton and Winamuck Mines. Lead carbonates and low-grade argentiferous galena were exhausted and in 1874 sulfide lead ore was mined and processed.

Production of lead-silver ores increased through the 1870's and 1880's. Lead ores were discovered in Butterfield Canyon and by 1884 these mines headed the lead ore producers in the District. From 1891-1892 there were 21 producing mines in the District, the largest being the Jordan, Brooklyn, Telegraph, Galena, Petro and Yosemite. With the completion of the Union Pacific railroad through Weber Canyon, 10 tons of copper ore were shipped from the Kingston mine.

During the 1890's many of the mine claims were consolidated and the Utah Consolidated Mining Company, the Boston Consolidated Mining Company, and the U.S. Mining Company were formed. The U.S. Mining Company drove the Niagra tunnel from Copperfield to the Jordan-Galena area and the Ohio Copper Company drove the Mascotte tunnel in 1905. The Ohio Copper Company also began in-situ leaching operations in the early 1900's.

The Highland Boy mine which operated in the 1890's was originally worked for gold. The mine was situated in Carr Fork with a cyanide mill established for gold extraction from oxidized ores. Highgrade sulfide copper was discovered at this mine and by 1896, copper was commercially shipped from this mine.

Boston Consolidated developed large tonnages of low-grade copper sulfide ore and the Ohio Copper Company located copper occurring in formations bordering the large porphyry intrusive in the District's center.

In 1903 the Utah Copper Company was organized and in 1904 the Copperton mill and the large scale mining of the low-grade copper porphyry in the Bingham District began. From 1904 to January 1, 1983, a total of 4.232 billion tons of porphyry ore, flux and waste material had been removed and copper production to January 1, 1983 stood at 11,182,674 tons. By-products from this operation include gold, silver, molybdenum, platinum, palladium and selenium.

Lead-silver-zinc production has fallen off since most of the large high-grade ore bodies have been depleted. The United States Smelting Refining and Mining Company and the Anaconda Company acquired mines and properties of many old Bingham producers, but at present, they are not in production.

According to James, A. and others (1961), the Bingham District has produced 4 billion pounds of lead and 1.5 billion pounds of zinc. The lead-zinc mineralization occurs erratically in veins and replacements unlike copper and molybdenum, which occur as porphyry deposits. Ninety-five percent of the lead-zinc production from the Bingham District has been derived from the calcareous portion of the Bingham quartzite. A typical cross-section showing the location of lead-zinc ores in a limestone host in the Bingham District is presented in Figure 8 and a generalized map of the metal zones and principal structures in the District is presented in Figure 9.

By 1926 Kennecott Copper Corporation held controlling stock in Utah Copper Company, but it was not until 1936, 73 years after mining had started in the District, that Utah Copper Company became an operating division of Kennecott.

In addition to the old mine tunnels and shafts, there are numerous waste dumps and tailings areas throughout the Bingham Canyon Mining District (Figure 6). It is important to recognize that surface water drainage through these abandoned mine workings and mine waste dumps may not only transport considerable sediment, but may result in the dissolution of the metals native to the host rocks. In fact, where metal sulfide ores are found, it is possible that acid waters (H_2SO_4) have formed and that natural leaching of metals has and still is occurring.

Two abandoned tailings areas which may require additional investigation with respect to potential adverse impacts on ground water are the Lark and Anaconda tailings sites.

The Lark tailings are located northeast of the abandoned town site of Lark in Section 28, R2W, T3S in the southwestern part of the study area and cover approximately 170 acres (Figure 2). The Lark tailings are from the old Ohio Copper Mine and range in depth from a few inches to over 14 feet. Total tonnage of these tailings is estimated at over 1.6 million tons.

Coring and sampling of these tailings to evaluate their metals content were conducted by Kennecott in the 1970's. Analysis for copper, molybdenum, gold and silver showed that copper was the only metal found in significant concentrations and that the majority of the copper has been meteorically leached and redeposited in the soils beneath the tailings. The tailings are primarily fine sand and silt with pH ranges from 3.3 to 6.3.

No detailed soil and geochemical studies of the Anaconda tailings have been conducted. However, since these tailings originated from Anaconda's abandoned copper mining operations, elevated copper concentrations are likely. These tailings are located immediately south and east of the 500 million gallon Bingham reservoir along the Bingham Creek drainage.

The Oquirrh Mountains and specifically the Bingham Canyon Mining District comprise the major recharge zone for the valley ground and surface waters east and northeast of the mountains. It is not surprising that with the large magnitude of the naturally occurring metals, particularly lead, zinc, silver and copper, as well as selenium, molybdenum and uranium in the Oquirrhs, that ground and surface waters east of the Oquirrh Mountains could have naturally occurring elevated concentrations of these constituents. Natural leaching, as surface waters percolate down through the rock units, as well as induced leaching through old mine workings could result in movement of metals from rock units into the ground and surface waters in the Jordan River Valley.

WHAT IS VELOCITY TOWARD JORDAN? MAYBE TO LATE TO EVALUATE BACKGROUND?

Waste rock at the mine consists of 1) iron-stained rock in the upper part of the mine that has been oxidized and naturally leached of its sulfide minerals, and 2) gray and white unoxidized rocks that contain less than 0.30% copper. The copper minerals of this latter material are commercially leached in the dumps, and the copper is recovered in the precipitation plant.

PURPOSE AND SCOPE

Bit Long?

The purpose and scope of the 5.25 year hydrogeologic/hydrologic study and of Task 1, of which this report partially completes, were developed by Kennecott and the technical and advisory groups and reviewed by Kennecott's environmental consultants, Dames & Moore and Intera.

The 5.25 year study is to accomplish the following:

1. Define the natural resources, the socioeconomic conditions, hydrogeology and hydrology in the vicinity of the Bingham Canyon Mining District.

2. Assess the historic and existing ground and surface water quality conditions in the vicinity of the Bingham Canyon Mining District, particularly with respect to the impacts from Kennecott's mining operations (Figure 2).

3. Obtain the necessary hydrogeologic and geochemical data required to evaluate the lateral and vertical extent of ground-water contamination.

4. Estimate contaminant movement in the ground water based primarily on actual field and laboratory water quality data, water level data and analytical rather than numerical solutions to ground-water flow equations. ? NO MODELING

The scope of work required to complete the 5.25 year study includes:

1. Review, compilation and summary of available natural resource, socioeconomic, hydrogeologic and hydrologic information in the UCD mine area (draft EIS, August 1984).

2. Continued collection, analysis and evaluation of water samples from monitor wells, private wells and surface water sample sites (1983-1989).

3. Drilling, logging, and sampling at new monitor well sites, (beginning in 1985), in strategic hydrogeologic locations, (both lateral and vertical), where definition of hydrogeologic conditions is determined to be critical.

4. Collection of geologic and water samples, during new monitor well drilling, at various depths, to evaluate vertical changes in lithology and water quality (1985).

5. Completion of a series of column and geochemical tests to evaluate the attenuation characteristics of the subsurface materials (1985-1986).

6. Preparation of five progress reports and completion of a final environmental impact evaluation (1989).

Task 1, of which this report partially completes, summarizes published hydrogeologic data pertinent to the study and presents geologic, hydrologic and hydrogeologic data which Kennecott has obtained in the mine area at the Utah Copper Division.

Most of the round 1 (1983-1984) comprehensive laboratory water quality data results from existing Kennecott monitor wells, surface water sites and private wells (excluding several irrigation wells) and 1982 water quality data were evaluated and are included in this report. Any additional round 1 1984 water quality data, historic water quality data from 1975, natural resource data and socioeconomic information will be presented in the August, 1984 draft EIS.

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Definition of existing ground and surface water conditions at this time is somewhat difficult and must be considered as preliminary, subject to change as the historic water quality data are evaluated in detail and as additional comprehensive hydrogeologic data and water quality data are obtained from new strategically located monitor wells.

FIELD AND LABORATORY PROGRAMS

The field program conducted for Task 1 report completion included:

1. A field inventory of Kennecott monitor wells. A total of 40 wells are not functional as water level or water quality monitor wells. A total of 51 Kennecott monitor wells were sampled, as indicated in Table B-1, Appendix B.

2. Unuseable Kennecott monitor wells (19) were grouted to prevent potential deep aquifer contamination. Many other monitor wells have been covered and destroyed (Table B-1, Appendix B).

3. A well inventory of private wells in the study area was completed. Well depths and open zones, water level data, well use, well location and well owner information were obtained from the Utah State Engineer's Office and from field investigations and are included in Appendix F. Well logs of private wells and Kennecott wells are included in Addendum 1.

4. Round 1 of Kennecott's comprehensive monitor well sampling was completed. A total of 51 Kennecott monitor wells were sampled, tested in the field for conductivity, temperature, pH, carbonate and bicarbonate, and analyzed for a comprehensive number of constituents in Kennecott's laboratory. Kennecott's Salt Lake City laboratory is EPA certified for drinking water contaminant analyses. Duplicate samples will be analyzed by the Utah State Department of Health, at their earliest convenience, as an additional quality assurance check.

5. Round 1 of surface water quality site sampling was completed. A total of twenty five (25) springs and streams and five (5) Kennecott facilities were sampled for comprehensive laboratory analyses and field tested for conductivity, temperature, pH, carbonate and bicarbonate. Results are listed in Table B-2, Appendix B.

6. Sixty four (64) representative private water wells which could be sampled were sampled for Round 1 analyses. Several irrigation wells could not be sampled but will, if possible, be sampled in the spring or summer of 1984. Since all of the laboratory results were not available for this report, 1982 data were included to aid in filling data location gaps. All round 1 water quality data and historic water quality data will be presented in the August, 1984 draft EIS.

7. Laboratory analyses were extensive and included analyses of 45 constituents at all sample sites and 57 constituents (which also included organics and radionuclides) at a few selected sample sites. Total as well as dissolved metals concentrations were analyzed.

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The field and laboratory sampling and analyses were conducted according to EPA recommended procedures (1983). The results of the laboratory analyses and the field information water quality sample site sheets are included in Appendices B and C, respectively.

Borehole geophysical logs, and borehole geologic logs and well construction data are included in Addendum 1.

STUDY AREA DESCRIPTION

The study area, as shown on Figures 1 and 2, covers approximately 200 square miles. It is bounded by the Bingham Canyon Mining District (Oquirrh Mountain Divide) on the west; the Jordan River and adjacent land area (approximately one mile east of the Jordan River), on the east; Butterfield Creek and adjacent land area approximately four miles south of Butterfield Creek, on the south; and north, to approximately 4700 South.

Bingham Canyon and Butterfield Canyon receive the major eastern drainage from the Oquirrh Mountains. Waters in Bingham Creek have been directed and are controlled and treated by Kennecott. Waters in Butterfield Creek flow east and eventually empty into the Jordan River.

Kennecott collects surface waters from Bingham Canyon (which includes North Ore Shoot water, pit waters and water from precipitation) into the large reservoir (500 million gallons) and the small reservoir (20 million gallons), treats the waters with lime and discharges the waters to approximately 400 acres of evaporation ponds to the east (Figure 2).

In 1962, a small 20 million gallon capacity reservoir was located in the lower Bingham Creek drainage. The large 500 million gallon capacity reservoir was constructed in 1965. Mine drainage and leach fluid along Bingham Creek were diverted to Kennecott's evaporation ponds. Prior to that, waters flowed down along Bingham Creek and emptied into the Jordan River. It is important to note that tailings from Anaconda's copper mining operations cover the creek channel just south of the large reservoir (Figure 2). Poor quality water, high in metals' concentrations have been transported down Bingham Creek. IS BINGHAM CREEK A LOSING STREAM?

Kennecott's waste dumps have been leached since the early 1930's (Figure 2). A leach collection pipeline system was installed in the mid 1960's and has been replaced with a more efficient cement lined leach collection system begun in 1980 (Figure 3). This system captures leach fluid for recycle and prevents leach fluid loss to the ground water.
MINIMIZES

The lined drainage channels (Figure 3) collect leachate and storm flow and convey it to the diversion structures. The bottom of the channels are removed to a depth of 1 foot to allow installation of the clay liner. Transition layers are dump waste material with a maximum size of 4 inches and rip-rap for the final layer is dump waste rock with a D50 size of 8 inches. Clay lining is compacted to meet the requirements in the State of Utah Standard Specifications for Road and Bridge Construction, 1979 Edition, Section 208.02 "Density Requirements."

Seepage cutoff trenches have compacted clay cutoffs keyed into bedrock (2 to 4 feet deep) to intercept ground water and a gravel filter to allow the water to flow to the surface where it is diverted by a concrete diversion structure into a concrete lined diversion canal. The concrete diversion structure is designed for a limited storage capacity and a limited outlet capacity to delay peak meteoric flows into the collection system. Approximately 2230 feet of concrete lined diversion canals are constructed from the diversion structures to the junction and/or drop boxes and flumes located at the junction with the return canal at North Copper, Keystone, North Keystone and Crapo draws (Figure 3). Concrete for the diversion canals is six inches thick and reinforced with a layer of welded wire fabric. All cement used in the concrete is a Type V, sulfate resisting and conforms to ASTM C150 specifications or Type 11 with pozzolan. Expansion and control joints for all canals are sealed with sikaflex-1A polyurethane elastomeric sealant.

Kennecott has an extensive network of deep and shallow aquifer monitor wells, and two deep production wells (Figure 2). The two production wells, designated K-60 and K-109, are located in Section 14, Township 3S, Range 2W, approximately 3 miles east of the town of Copperton. Well K-60, open from 430 to 645 feet, is a standby production well which was pumped at 1700 gpm, and well K-109, open from 403 to 540 feet, is the current production well and pumps at around 2500 gpm. Well K-109 is used for culinary water, wash water, precipitation plant water and any other use for which good quality water is needed.

REGIONAL GEOLOGY

Physiography

Kennecott's Bingham Mine pit and leach dumps are located in north central Utah in the eastern part of the Great Basin in Salt Lake County, in and along the foothills of the Oquirrh Mountains. The Oquirrh Mountains rise to more than 9000 feet, are bounded on the west by the Tooele Valley, on the east by the lower Jordan Valley, on the north by the Great Salt Lake, and on the south by the Traverse Mountains. The Oquirrh Mountains are a typical north-trending block-faulted range of approximately 25,000 feet of Pennsylvanian and Permian strata of primarily limestone, sandstone and siltstone.

The terrain, from the Oquirrh foothills into the valley, is of moderately low relief, with low, rolling hills and shallow gulches. North facing slopes are primarily covered with oak and maple scrub brush. Juniper groves are numerous with the ridges and south-facing slopes usually barren, except for grass and scrubby sage brush. Wheat fields are plentiful in the Jordan Valley and the only permanent naturally flowing streams are Butterfield and Bingham Creeks.

The western-most edge of the Oquirrhs is characterized by steep slopes cut by moderately deep gulches, V-shaped bottoms, fairly steep side slopes and slightly rounded ridges (Figure 3). Low rounded foothills comprise the volcanic area further east along the Oquirrh foothills. Broader gulches and gentler side slopes characterize this maturely dissected pediment. The eastern-most edge of the Oquirrhs is characterized by a broad gentle valley slope cut by shallow narrow gulches and includes the Bonneville Bench. These three zones are separated topographically as a result, in part, of block faulting. Moving from west to east, sedimentary rocks and granite or diorite intrusives are followed by volcanic rocks and porphyry intrusives, followed by deeper gravel and lake-bed deposits which extend into the valley.

Kennecott's operations and the study area are located in the Jordan River Basin (Figure 1). The Jordan River enters Salt Lake County at Jordan narrows, a gap in the Traverse Mountains, and flows northward to the Great Salt Lake through the Jordan Valley. The valley floor elevations range from 4200 feet at the Great Salt Lake to around 5200 feet along the foothills of the Oquirrhs, and to around 8,000 to 9,000 feet in the Oquirrhs.

The climate ranges from semi-arid in the valley to humid in the highest mountains. Surface water recharge into the valley soils and parts of the underlying ground-water reservoir are generally good, Hely A. G. and others (1971).

The Jordan River, several creeks draining parts of the Wasatch Range, and the unconsolidated saturated valley fill, which locally is more than 2,000 feet thick, comprise the principal water sources in the county, Hely, A.G. and others (1971).

The area drained by the Jordan River Narrows is approximately 3,000 square miles of mountain and valley terrain. The head of the Jordan River is located approximately 7.5 miles upstream, and it is the natural outlet for Utah Lake. The outflow to the Jordan River is controlled by gates and pumping.

The climate of Salt Lake County is characterized by a wide range of temperatures and is strongly influenced by altitude and topography.

The mean annual precipitation in the Jordan Valley generally ranges from 14 to 16 inches, and in the Oquirrh Mountains the mean annual precipitation generally ranges from 20 to 25 inches. Temperatures range from a low normal average of around 20°F in January to a high normal average of around 80°F in July.

According to the Hely, A. G. and others (1971), the mean annual evaporation rate in the Jordan Valley is around 65 inches, and the mean annual evaporation rate at 8,000 to 9,000 feet (i.e. in the Oquirrhs) is around 50 inches.

Maximum evaporation occurs in July and in general, the period from May through September experiences the most evaporation.

Precipitation greatly exceeds evapotranspiration in the mountains during the late fall and winter. The large surplus of moisture in the snowpack results in spring runoff, deep seepage and contributes much to the soil moisture used by vegetation. By late summer or fall only a small moisture deficit occurs. In the valley, the winter surplus has run off or seeped into the ground and a large deficit results during most of the growing season. Estimated annual average evapotranspiration in the Oquirrh Mountains is 13 inches and annual average evapotranspiration in the Jordan Valley in areas where the only moisture available to plants is from precipitation, is around 65 inches.

Stratigraphy

In the 25,000 feet of Pennsylvanian and Permian strata that comprise the Oquirrh Mountains, over twenty-five mappable units are recognized. A generalized stratigraphic section of the Great Basin and a list of Pennsylvanian and Permian units within the Oquirrh Mountains are presented in Table 2.

The Permian rocks in the Oquirrh Mountains are approximately 10,000 feet thick. The Park City Formation limestones, Diamond Creek Formation sandstones, Kirkham Formation limestones, Clinker Formation sandstone and chert beds and the Curry Formation chert pebble conglomerate crop out to the north of the Bingham Copper Pit in the Oquirrh Mountains (Figure 6).

The Pennsylvanian system in the Oquirrh Mountains is comprised of cyclical limestones and sandstones that are lithologically and petrologically similar but not identical. Welsh, J. E. and James, A. H. (1961) use the term Oquirrh group to include the Bingham Mine Formation (the limestones and quartzitic sandstones intruded by the Bingham stock), the Butterfield Formation (9 mappable limestone members belong), the White Pine Formation (limestones and interbedded sandstones), and the Maple Formation, (the cyclical sandstones and limestones located above the block shales of the Manning Canyon Formation and below the base of the White Pine Formation). The Pennsylvanian Oquirrh group primarily outcrops in the area north and south of the Bingham Canyon Pit.

The locations and thicknesses of the Permian and Pennsylvanian limestone beds are important factors to enhancing the quality of waters that infiltrate these rocks. Because most of the lead-zinc deposits and mines are located within calcareous rocks, some neutralization of naturally occurring and mine-induced acid waters has resulted. Reduced dissolved metals concentrations in the ground and surface waters could thereby follow, as the waters percolate through the limestone units.

Tertiary volcanic rocks, (undifferentiated, flows, breccias and agglomerates), outcrop along the eastern edge of the Oquirrhs in the southern part of the study area.

Tertiary intrusive rocks, (granite or monzonite stocks, sills and dikes, granite porphyry of Bingham stock, and rhyolite-quartz latite or monzonite porphyry) outcrop in the Bingham Canyon Pit and to the east, south of the town of Lark.

Tertiary sediments of the Salt Lake Formation, the Harkers fanglomerate, outcrop east and north of the town of Lark along the eastern foothills of the Oquirrhs. This fanglomerate is a poorly sorted calcium carbonate cemented silt to boulder size quartzite, sandstone, limestone, andesite and latite. Locally, these deposits are as much as 300 feet thick.

Quaternary unconsolidated deposits include alluvium, colluvium, fanglomerate and lake deposits of recent age and older alluvial and talus deposits and lacustrine alluvial and eolian deposits of Lake Bonneville of Pleistocene age. Wavecut terraces and near-shore bars and spits can be observed in the Quaternary deposits in the valley as a result of Lake Bonneville effects.

GEOLOGY OF VOLCANIC & SEDIMENTARY (GRAVELS) DEPOSITS ARE INSUFFICIENT

A generalized east-west cross section from Markham Peak to Twin Peaks (Figure 5) illustrates that the Oquirrh Mountains and Salt Lake Valley are part of an east-tilted block modified by faulting along several zones beneath the alluvium.

According to Smith, W. (1961), there are two types of gravel deposits in the Jordan Valley, those composed of volcanic material and those composed of sedimentary material.

Volcanic gravel exposures are few but are located in Barney's Canyon, in the Lark area and on the surface, immediately south of the Lark tailings disposal area. Some ash deposits interbedded with the gravels occur at Clay Hollow, in a railroad cut north of Copperton and in a railroad cut between Bingham Canyon and Midas Gulch. The ash deposits are composed of angular shards and some whole and some broken tiny spherules or glass bubbles. These ash deposits are believed to have accumulated from ash falls from a final stage of volcanic activity. They appear to be remnants of larger deposits that were first removed primarily by erosion and then buried by gravel deposition.

Sedimentary gravels cover most of the volcanics and range from a few feet in depth along the mountain block to over 50 feet in depth along the eastern edge of the volcanics to over one thousand feet in less than a mile from the Oquirrh foothills. Because of shifting channels and resulting cutting and coarse cross-bedding during sediment deposition, the sedimentary gravels range from unconsolidated to cemented, are generally poorly sorted and roughly stratified with soil and clay layers.

Structure

According to Welsh, J. E. and James, A. H. (1961), the Oquirrh Mountains and basin are tectonic features which formed in the late Paleozoic era. The Oquirrh Mountains are a north-trending block-faulted range in the eastern part of the Great Basin. When the Oquirrh basin formed, large blocks of the Oquirrh formation slid eastward and formed the Oquirrh Mountains. North-south lenticularity and facies changes are minor. East-west lithologic changes in the Pennsylvanian rocks are much more striking.

According to Cook, K.L. and Berg, J.W. (1961), the Jordan Valley has been interpreted from geophysical and geological data as a graben. This graben is approximately 25 miles long and 16 miles in maximum width. The northern part is narrow and constricted and extends from Murray to the vicinity of Beck's Hot Springs. The southern part is characterized by a broad gravity low and extends from Herriman to Draper.

Along the northwest margin, the valley fill is approximately 1985 feet deep, the northeast approximately 750 feet to 1170 feet deep, the eastern margin is approximately 1027 feet deep, in West Jordan it is approximately 1900 feet deep and the southern margin is approximately 700 feet deep.

The Jordan Valley graben is bounded on the east by the Wasatch fault zone, on the west by a fault zone running from Granger to Lark, on the south by an easterly trending fault zone along the northern edge of the Traverse mountains.

A detailed discussion of the structure of the Bingham District is presented by James, A. and others (1961). Principal structures are shown in Figures 7, 8 and 9. The Oquirrh group has been deformed primarily by three strong assymetric folds of shifting axial trend, the Middle Canyon syncline, the Bingham syncline, and the Copperton overturned anticline (Figure 9). Folds and thrusts appear to converge on the Bingham porphyry stock. Two groups of high-angle faults of considerable displacement intersect here in geometric patterns related to the outline of the porphyry bodies and localization of ore.

Folding is cut by strong faults which have been classified into four major groups:

1. The North Oquirrh thrust,

2. The Midas or North Fault, a low angle overthrust which cuts across the axis and links of the Copperton anticline and limits lead-zinc mineralization,

3. The Occidental and the Bear Faults, and

4. Northeast-striking, high-angle faults well displayed in Middle Canyon.

The following structural history is based on discussions in the Guidebook to the Bingham Mining District presented by the Society of Economic Geologists (1975). The Bingham Mining District occurs along the Uinta axis and includes the east-west Park City, Alta-Cottonwood, Bingham trend of intrusives and ore mineral-producing districts. The Cottonwood uplift westerly extension of the Unita axis can be traced through the Traverse Mountains separating Utah and Salt Lake Valleys, to the high peaks of the Oquirrh range 4 miles south of Bingham. In the Oquirrhs, the axes of folds plunge northward and southward from the center of the uplift which can be roughly traced westward from the Oquirrh range to the Stansbury Mountains through the east-west-trending South Mountain range separating Rush Valley from Tooele Valley.

The Bingham district (Figure 6) is characterized by asymmetrical compressional folds and thrust faults on which two systems of high-angle faults intersecting roughly at right angles have been superimposed. So much deformation and fracturing occurred that easy access was available to magmatic material and, later, hydrothermal solutions. The highly fractured permeable central portion of the Bingham stock is the center of mineralization for the Bingham district. Transverse high-angle faults and fissures, (particularly the northeast-southwest system), and bedding plane faults, provided channelways for ore-bearing solutions to migrate out from the Bingham stock. The channelways and the limestones which the solutions contacted were mineralized. Low-grade disseminated copper ore in and around the Bingham stock, fissure-filled ore deposits of copper or lead, and zinc and limestone bedding replacement deposits of copper-in-skarn rock or lead-zinc in unmetamorphosed limestone, comprise the three types of ore deposits in the district.

The structural history of the Oquirrh Mountains in the Bingham district is described by James, A. and others (1961) as follows:

1. Intraformational slides and adjustments (Kirkman-Diamond Creek breccias).
2. Folding (Middle Canyon, Bingham, Copperton folds).
3. Bedding plane faulting (bedding plane adjustments and bedding plane faulting were important throughout the structural history of the district, but are usually difficult to measure and define).
4. Overturning (Copperton fold).
5. Thrusting -- the North Oquirrh thrust, the Midas thrust.
6. High angle reverse faulting (northwest) - (Bear fault).
7. Northeast-striking, high angle faults (Clipper Peak faults, west Mountain faults).
8. Intrusion of stocks and sills.
9. High angle northwest faulting (Occidental fault, renewed movement on Bear fault, Giant Chief fault).
10. Intrusion of dikes and sills.
11. Post-intrusive fracturing.
12. Volcanic activity.
13. Basin-Range faulting.

As shown in Figures 6 and 9, numerous northwest-southeast and northeast-southwest trending faults run through the Bingham district. The folds and faults are extensive at a distance of two or more miles from the Bingham Mine. Structural complexity increases closer to the stocks and mineralized center. Fractures are closer, fracture sets are present and continuity is frequently interrupted.

According to the Society of Economic Geologists (1975), the degree of fracturing and permeability have controlled in part the metal and alteration mineral zones in the Bingham district. Five concentric overlapping metal zones located around the quartz monzonite porphyry phase of the Bingham stock are barren core, molybdenum, copper, iron, and lead-zinc-silver. Molybdenum occurs as fracture-controlled molybdenite, copper minerals (chalcopyrite, bornite, and primary chalcocite) as disseminations and in vienlets, iron as pyrite with some magnetite and hematite and lead-zinc-silver includes galena and sphalerite.

REGIONAL SURFACE WATER AND GROUND WATER HYDROLOGY

Surface Water

The following section is based on the report, "Water Resources of Salt Lake County, Utah" by Hely, A. G. and others (1971).

As illustrated in Figure 1, the study area includes approximately 200 square miles in Salt Lake County, in the Jordan River basin.

The mean annual surface inflow to the Jordan Valley, during 1964-1968 water years, was 463,000 acre-feet, and the outflow to the Great Salt Lake was 324,000 acre-feet. Flow at the Jordan River Narrows during this time period averaged 226,200 acre-feet per year.

The Jordan River is a gaining stream in the Jordan Valley. It receives inflow from surface water sources as well as from ground-water sources. The Narrows, effluent from eight sewage plants, Big and Little Cottonwood Creeks and Mill Creek contributed as surface water recharge to the river totaling 89,400 acre-feet annual average for the 1966-1968 water years. Ground-water recharge to the river for the same time period was computed at approximately 147,000 acre-feet annual average.

Water quality along the Jordan River degrades between the Jordan Narrows and the head of the North Jordan Canal, above the diversion dam at 9400 South, due to return flow and drainage from irrigated fields. At 9000 South, below the diversion dam, the water quality improves because of ground-water inflow. From 9000 South to 5800 South the quality slightly degrades, and between 5800 South and Cudahy Lane the quality improves as the river gains from ground-water seepage and tributary inflow. The poor water quality in the Goggin drain near Magna, (which primarily receives water from the Jordan River), is due to return flow from irrigation and naturally occurring poor quality ground-water seepage. A summary of water quality data from the Jordan River is presented in Appendix E from Hely, A. G. and others (1971) and Table B-2, Appendix B.

On the basis of measurements taken during 1964-1968 along eight principal streams from the Oquirrh Mountains, and some discharge from mine tunnels receiving ground water, the mean annual surface water discharge from the Oquirrh Mountains is low and is estimated to be around 7,000 acre-feet.

According to Hely, A.G. and others (1971), surface waters from the Oquirrh Mountains not associated with historical mining and mine wastes (Rose Creek, Dry Fork and Coon Creek) are of calcium bicarbonate type with dissolved-solids concentrations ranging from 200 to 500 mg/l. Waters from Butterfield Creek, Keystone Gulch and Bingham Creek, those associated with mining activities, are of calcium sulfate type with dissolved solids in excess of 900 mg/l.

CHECK HISTORY FOR INFO ON KENNECOTT USING OTHER DRAINAGES

Is Bingham Creek A Losing or Gaining Stream?

Hely, A. G. and others (1971) state, "Mining is a dominant influence on the chemical quality of water in some parts of the Oquirrh mountains. Leaching of the products of oxidation of lead, zinc, and copper sulfides in the Bingham area yields waters containing large quantities of sulfate, iron, and other ions. Acid produced in the oxidation and leaching process is neutralized by the carbonate rocks of the Oquirrh Formation. In Bingham Creek near Copperton, however, the water flowing from the Kennecott Copper Corp.'s leaching operations is acid. In addition to the constituents listed in table 15, (of Hely, A.G. and others (1971) see Table E-1 herein), this water contains as much as 300 mg/l of copper, 250 mg/l of zinc, and 4,000 mg/l of iron. The chemical quality of mine drainage and its effect is discussed in the section on chemical quality of ground water."

While Kennecott discharged low pH waters down Bingham Creek and along the leach dumps in the past, with the completion of the leach collection system and surface water treatment, Kennecott no longer discharges acidic leach waters down Bingham Creek and thereby minimizes further impacts to the water resources.

GROUND WATER

Valley Fill

The rocks of key hydrogeologic importance are those that constitute the valley fill. These rocks are mainly unconsolidated, very porous and permeable and may yield large quantitites of water. Although the water-yielding capacity varies with the rock type, depositional history and saturated thickness, the valley fill constitutes the main ground-water reservoir in the valley (Figures 12 and 13).

The valley fill principal rock types are clay, silt, sand, gravel, tuff and lava. These deposits were formed by: 1. lake deposition (in beaches, spits, bars, deltas, or on the lake bottom, 2. mud-rock flows, 3. alluvial fans, 4. sand dunes, 5. glacial deposits, 6. flood-plain deposits, 7. ash falls or 8. lava flows.

No stratigraphic sequence is applicable to the valley as a whole because the type of material deposited was determined by the location of a canyon mouth, mountain front or valley stream channel. Areas inundated by Lake Bonneville received lake deposits, others were eroded by lake currents and areas where lake deposits occurred may have later been subjected to extensive stream erosion. Other areas were subsequently covered by post-lake stream deposits. Marine, I.W. (1960) divided the Jordan Valley into six ground-water "districts" according to the types of materials found in the districts resulting from the methods of deposition. The area north of the Traverse Mountains and south of Magna, east of the Oquirrh Mountains and west of the Jordan River (the study area) is defined as the "West Slope District." According to Arnow, T. (1965), the principal rock material in this district consists of boulders, gravel, sand, silt, clay and limestone of stream and lake-bottom sediment deposition. The thickness was estimated at more than 1400 feet.

The northern boundary of the "West Slope District" separates the Tertiary rocks from the more northern pleistocene lake deposits. The Granger fault serves as the northwest structural boundary. Within the Jordan Valley, a large proportion of the Tertiary deposits are semiconsolidated clay, sand and gravel interspersed with lava and cemented layers of sand and gravel. According to Arnow, T. and others (1970), the average specific capacity of wells completed in these Tertiary deposits is less than 5 gpm/ft.

The Quaternary deposits unconformably overlie either Tertiary deposits or pre-Tertiary bedrock. The Quaternary deposits are unconsolidated and consist mostly of materials ranging in size from clay to sand, although they do contain layers of gravel or boulders. According to Arnow, T. and others (1970), well records indicate that wells in the Quaternary deposits show an average specific capacity of 60 gpm/ft. Cemented low permeable calcium carbonate accumulations are common in acid regions such as in the Jordan Valley, and such accumulations (termed caliche, hardened caliche or hard pan) have been noted in driller's logs and generally reflect the upper part of the Tertiary deposits.

According to Arnow, T. and others (1970), the altitude of the base of the Quaternary deposits is around 5000 feet at Copperton, at around 4500 feet approximately 2.5 miles east of Copperton along Bingham Creek and around 4000 feet at the Jordan River approximately 9.2 miles east of Copperton. Therefore, the thicknesses of the Quaternary deposits are around 400 feet near Copperton, 600 feet approximately 2.5 miles east and 800 feet approximately 9.2 miles east of Copperton.

The Quaternary deposits are thickest in the northern part of the valley where they exceed 2200 feet, and thinnest adjacent to the mountain fronts and in the area west of Kearns, where they are generally less than 200 feet thick.

The contact between the Quaternary deposits and underlying pre-Tertiary bedrock can be interpreted from well driller's logs at the point where a consolidated rock as limestone, shale, sandstone or bedrock is encountered.

The contact between the Quaternary deposits and underlying Tertiary deposits is not easy to depict. However, the contact can be estimated where lava beds, conglomerate, hard pan or various types of cemented materials greater than 3 feet thick are first encountered.

Based on a shaft in Bingham Canyon and a well in Butterfield Canyon located approximately one mile southeast of the abandoned town of Lark, bedrock (the Oquirrh Formation) is 200 to 250 feet below the surface along Bingham and Butterfield Creeks. It is believed that these creeks may have cut steep-walled canyons before they were filled and recut to their present depths.

In the southern alluvial fan subdistrict of the West Slope District, gravel, clay and boulder deposits are encountered from 200 to 500 feet in depth. These deposits appear to be old alluvial fans whose topographic forms have been erased by later geologic events. Above these alluvial fan deposits are shore deposits of the Bonneville group. Kennecott's evaporation ponds are located near a spit, a large V-shaped bar of the Provo stage of Lake Bonneville (Figure 4).

In general, the West Slope district is of even gentle slope. Minor modifications of this general slope are seen at the evaporation pond spit, the Benion spits, the Bonneville wave cliff, the Provo wave cliff, beach deposits around the Stansbury level, the Bingham delta lobe and sand dunes (Figure 4).

The surficial deposits in the valley are not necessarily representative of those at depth. It is difficult to correlate individual water-bearing zones throughout the valley fill. However, the fill has been divided into an upper more permeable zone of unconsolidated rocks of Quaternary age and an underlying less permeable zone of semiconsolidated and consolidated rocks of Tertiary age. A map of the estimated thickness of saturated deposits of Quaternary age in the Jordan Valley is included in Figure 13.

Based on the information presented by Hely, A. G. and others (1971), ground water in the Jordan Valley occurs in 1. unconfined shallow perched aquifers, 2. a shallow unconfined aquifer overlying the artesian aquifer, 3. a deep unconfined aquifer between the deep artesian aquifer and the mountains and 4. a deep confined (artesian) aquifer. The ultimate source of most of the ground water withdrawn from wells is the principal aquifer, of which 3 and 4 above comprise (Figures 13 and 14).

Shallow Unconfined Aquifer

The shallow unconfined aquifer is separated from the deep confined aquifer by a 40 to 100 foot thick low permeability unit. The shallow aquifer consists of clay, silt, and fine sand and in some areas the permeability of the shallow aquifer is only slightly greater than that of the underlying bed. The maximum thickness of the shallow aquifer is about 50 feet. The shallow aquifer is seldom used for water supply because of the poor water quality and low yield. The shallow aquifer receives recharge from surface water seepage from waters diverted from the Jordan River for irrigation. Where the potentiometric level in the deep aquifer extends beyond the confining bed, waters moving up from the deep confined aquifer through the confining bed recharge the shallow aquifer.

Perched Aquifer

Perched water occurs where the bottom of the confining bed lies above the deep water table. An unsaturated zone exists between the deep water table and the perched body of water above it. The perched zones are only a few tens of feet thick, with the largest zones being extensions of the shallow unconfined aquifer. Perched zones have been noted west and southwest of Kearns, east of Midvale and between Herriman and Riverton (Figure 13).

Confined Aquifer

The confined aquifer consists of Quaternary deposits of clay, silt, sand and gravel, hydraulically connected, with individual beds ranging in thickness from less than one foot to several tens of feet. This aquifer exceeds 1000 feet in thickness in the northern part of the valley. The aquifer consists of many lenses of fine-grained material, from a few feet to 20 feet thick which tend to confine water in each of the individual sand and gravel beds.

The confined aquifer is overlain by low permeability Quaternary deposits of clay, silt and fine sand which act collectively to form one bed running in thickness from 40 to 100 feet. This confining bed lies between 50 and 150 feet below land surface and is co-existive with the outlines of the confined and perched aquifers illustrated in Figures 12 and 13.

The potentiometric surface of the confined aquifer is above the land surface in low-lying parts of the Jordan Valley, such as in the northern part and an area along the Jordan River (Figure 14).

It is believed that the confined aquifer actually extends to the edges of the Jordan Valley where the confining bed pinches out and the deep confined aquifer is actually an unconfined aquifer. This aquifer near the valley edges, does not yield much water because the water-bearing rock units are thin; also because the depth to water is generally greater than 500 feet and it is uneconomical to pump.

Tertiary Aquifers

The confined aquifer is underlain by Tertiary and pre-Tertiary deposits of generally low permeability and yield. There are, however, three areas where the Tertiary deposits yield some water. These include an area near the town of Kearns, an area near Murray, and an area between Herriman and Riverton (Figure 13).

Hydraulic Properties of the Shallow Unconfined Aquifer

(T) and (S) values for the shallow unconfined aquifer are based primarily on lithology. (T) values are summarized in Figure 16. (T) values range from 1300 ft^2/day, where the largest values of (T) are near Murray, where the saturated thickness exceeds 25 feet and contains coarse sand and gravel deposits. Because much of the shallow unconfined aquifer is comprised of sand, silt and clay, a value of S of about 0.15 is reasonable.

Hydraulic Properties of the Principal Aquifer

Hydraulic properties of the principal aquifer in the Jordan Valley were determined by Hely, A. G. and others (1971) based on 25 drawdown and recovery tests in wells for which pumping effects were observed in 73 observation wells. Specific capacity values from 75 other sites were used to estimate transmissivity. Transmissivity (T) and storage (S) values are summarized in Figure 15.

Hydraulic Properties of the Principal Aquifer continued

The largest (T) values of the principal aquifer (around 50,000 ft^2/day) are in the eastern part of the valley and in some areas between Riverton and Herriman, where the aquifer consists of thick deposits of coarse sand and gravel. The samllest (T) values are near and west of Kearns (where some water may be obtained from underlying Tertiary deposits) and southeast of Draper. Permeabilities generally decrease away from the mountains. Transmissivity increases to the north because of greater aquifer thickness.

The principal aquifer is unconfined near the mountains where the specific yield is around 0.15. Where the principal aquifer is confined, the storage coefficient ranges from .0001 to .01.

Hydraulic Properties of the Confining Unit

The vertical hydraulic conductivity of the confining unit separating the shallow unconfined aquifer from the deep confined principal aquifer has been estimated to be around .025 ft/day, an average for the entire valley, Hely, A. G. and others (1971). According to Walton (1970), representative permeability values for clay and silt range from $1x10^{-5}$ to 0.3 ft/day. The ability of this confining unit to transmit water is poor and thus serves to limit ground water flow from the shallow poorer quality aquifer to the deeper principal aquifer.

Water Quality

Ground water in the Jordan Valley is primarily withdrawn from a deep principal aquifer (which consists of a deep unconfined aquifer near the mountains and a deep confined aquifer in the valley) and some is withdrawn from an overlying shallow unconfined aquifer. Ground water from the principal aquifer is generally suitable for municipal use, irrigation and/or most industrial uses. However, water from some areas, Hely, A. G. and others (1971), is suitable only for uses without stringent quality requirements. The water quality in the principal aquifer in the east near Big and Little Cottonwood Creek is of excellent quality, with dissolved-solids concentrations ranging from 100-250 mg/l. Dissolved-solids concentrations increase to 2000 mg/l near the Great Salt lake (Figures 10 and 11).

According to Hely, A. G. and others (1971), "The chemical quality of water in the principal aquifer is being degraded locally in the southwestern part of the valley, where seepage losses from irrigation and mining infiltrate the ground-water reservoir. Degradation of water quality in the principal aquifer has not been observed in other parts of the valley. Water quality in the shallow unconfined aquifer is being degraded at many places, however, by seepage from irrigation and other sources. Water quality in the deposits of Tertiary age probably is not being degraded."

Consolidated Rock Aquifers

The following discussion of the regional hydrogeologic environment is summarized from Hely, A. G. and others (1971). The rocks in the region were classified into four divisions based on permeability. They are, in order of decreasing permeability:

1. Weber Quartzite of Pennsylvanian age - Quartzite and limy sandstone with some interbedded limestone and dolomites; greatly fractured in places; reported to be the principal source of water in the mines of the Park City Mining District on the east side of the Wasatch Range.

2. Rocks of Mississippian age - Predominantly limestone in which bedding planes, joints, and other fractures are subject to enlargement by solution; these rocks are known to be cavernous in Neffs Canyon.

3. Rocks of Pennsylvanian (excluding the Weber Quartzite), Permian, and Mesozoic age and sedimentary rocks of Tertiary age older than the Salt Lake Formation -- shale, siltstone, sandstone, conglomerate, and limestone, whose original porosity for the most part was not great and has not been appreciably changed by secondary processes.

4. Precambrian, Cambrian, and Devonian rocks, and intrusive and volcanic rocks of Tertiary age -- crystalline rocks, shale, tillite, limestone, and volcanic rocks having either low original porosity or porosity that has been decreased by secondary processes.

JORDAN VALLEY WATER RESOURCES

Sources of water available to the Jordan Valley are: 1. precipitation on the valley, 2. streams in the adjoining Wasatch Range and Oquirrh Mountains, 3. the Jordan River, 4. imports through canals and pipelines and 5. ground water.

The southernmost boundary of the study area includes the inflow at the Jordan River Narrows (Figure 1) which drains approximately 3000 square miles. Although water from the Jordan River is not suitable for municipal use, (due to contamination), it is still the principal source of water in the county for irrigation and heavy industrial use. The Jordan River receives contaminants from natural sources and man, downstream from the Jordan Narrows. According to Hely, A. G. and others (1971), municipal, industrial and agricultural wastes which enter the Jordan River within the Jordan Valley render the quality of water in the lower part of the river unsuitable for any uses other than those with the lowest quality requirements, such as cooling in industrial or power plants, irrigation of meadows and maintenance of water fowl-management areas.

Salt lake County is one of the most highly developed regions in Utah. According to Hely and others (1971), the population in 1975 at 604,000 required 1.024×10^{11} gallons of water for municipal and industrial uses. The population in 1985 is projected to be 794,000 and water requirements are estimated to be 1.4×10^{11} gallons of water for municipal and industrial uses. Projections for the year 2000 are a population of 1.043 million and 1.95×10^{11} gallons.

During the period from 1932-1968, ground water withdrawals in the Jordan Valley nearly tripled, although the amount of ground water in storage increased by 2.6×10^{9} gallons. According to the U.S.G.S., Hely and others (1971), with the exception of the area northwest of Magna, mean annual ground-water withdrawals could be at least doubled. Withdrawals from the northern part of the Jordan Valley would thus salvage water which is currently being lost by evapotranspiration.

The following discussion is based on a 1981 water use data report issued by the Department of Natural Resources, Division of Water Rights. According to Hooper, D. and Schwarting, R. (1982), the 1981 state totals of water diverted by public water suppliers were approximately 138.57 billion gallons total, of which 46.14 billion gallons were from surface water (33%) and 51.5 billion gallons (37%) were from ground water from wells (Figure 17).

In 1981 Salt Lake County public water suppliers diverted approximately 55.4 billion gallons total of which 32.1 billion gallons came from surface water (58%), 2.1 billion gallons came from ground water from springs (4%) and 21.2 billion gallons came from ground water from wells (38%). The total percentage of water used by Salt Lake County relative to the entire state was around 40%. The state average water use per capita is 240 gallons per day and the Salt Lake County water use per capita is 204 gallons per day.

Tables 3 and 4 from Hooper, D. and Schwarting, R. (1982) list the reported water diversions by the specific public water suppliers and the daily per capita withdrawal rates per public water supplier. Of key interest, with respect to proximity to the Kennecott ground-water study area, are public water suppliers for Copperton, Granger-Hunter I.D., Herriman, Hi-Country Estates, Johnson/Anderson Subdivision, Kearns, Magna, S. L. Metropolitan Water District, S. L. County W. C. D., Riverton, South Jordan, Taylorsville-Bennion and West Jordan. Total water use from these suppliers for 1981 was around 14.7 billion gallons or 10% of the state's total of 138.57 billion gallons. Spring and well water use totaled around 9 billion gallons, only 10% of the total 92.43 billion gallons of ground water used by the state.

Much of the ground water from the principal aquifer in the Jordan Valley is used for municipal, irrigation and domestic purposes without any treatment other than softening. Published water quality data from 58 wells used for municipal and domestic supply are included in Appendix D. Many of these wells yield water in excess of 500 mg/l total dissolved solids and exceed the 250 mg/l EPA drinking water chloride and sulfate concentrations. Most of these wells are located in the western part of the valley where chloride or sulfate levels exceed EPA drinking water standards.

Deeper wells of higher yield used to distribute water to more than one user (i.e. municipal, irrigation and/or multiple home distribution) in the study area were sampled (Table B-1, Appendix B). The wells included those of Riverton City, Herriman City, Copperton City, Kennecott, the Salt Lake City Conservancy District, Westland Hills and the Provo Water Users. The limited field water quality data from these wells (Appendix C) indicate these wells intercept good to moderate quality ground waters. The complete suite of laboratory water quality data was not available for this report but will be included in the August, 1984 draft EIS.

SITE HYDROGEOLOGY

Introduction

The following discussion is based on existing hydrogeologic information from published documents, Kennecott's well logs and well logs obtained from the State Engineer's office, and water level data. Valid and detailed site specific hydrogeologic definition is not possible until drilling and well logging are completed and water quality and water level data are collected at strategically located new monitor well sites. Geologic cross sections prepared by Kennecott in the 1970's and updated for this report (with sulfate concentrations shown and current water levels and well depths) are presented in Figures 19, 20 and 21. The locations of the cross sections are shown on Figure 2.

DOES NOT REALLY SHOW A CONFINING ZONE UNTIL W-108 OR 12-dbc

Alluvial (Shallow) Aquifer

Water level and water quality data from some of Kennecott's monitor wells indicate the presence of an upper shallow aquifer and deeper aquifer.

Ground water in the upper shallow aquifer as in the deeper confined aquifer, flows from the Oquirrh Mountains east to the Jordan River (Figure 13). The U.S.G.S. delineates the confined and shallow unconfined aquifers as beginning at a distance approximately 5 miles east from the foothills of the Oquirrhs. Kennecott well log data indicate the presence of a shallow aquifer at a considerable lesser distance from the Oquirrhs. The vertical and lateral boundaries of the shallow and deep aquifers and confining zone will be better defined following detailed logging during new monitor well drilling.

AN ABSOLUTE MUST.

Based on the water level elevation data available, the lateral hydraulic gradient in the shallow aquifer and deep aquifer east of the reservoir are approximately .005 foot/foot and .01 foot/foot, respectively.

Shallow ground-water elevations in wells K-84 and K-85 located just east of the Bingham Reservoir (the water level at approximate elevation + 5,295 ft) have water level elevations of around 5,211. East of these wells, approximately 400 feet, the shallow K-100 series wells have water level elevations of around 5190 to 5200 feet while the deeper K-100 series wells have water level elevations of around 5160 feet. The ground-water level elevation in shallower wells located approximately 1100 feet east of the reservoir is around 5195 feet and the deeper wells in this area have water level elevations of around 5160 feet.

There is a downward vertical hydraulic gradient in the area near the reservoir and to the east for a distance of at least 5000 feet. The water level data from existing monitor wells indicate head differentials in the shallow and deep aquifers of around 30 feet in this area. Water levels are believed to be affected by Kennecott's reservoir.

According to Hely and others (1971), the shallow unconfined aquifer is composed principally of clay, silt and fine sand and in some areas has a permeability only slightly greater than that of the underlying confining bed. The maximum thickness of this aquifer is approximated at 50 feet. Recharge is principally from the Jordan River and from vertical movement up from the principal aquifer. Seepage of poorer quality waters from irrigation, canals and Kennecott's reservoir and evaporation ponds also recharge the upper shallow water table aquifer.

NOT THE SAME AS FIGURE 19.

According to Hely and others (1971), values for transmissivity and specific capacity range from 1300 ft^2/day to 2700 ft^2/day and from 0.10 to 0.20, respectively. Because the saturated thickness of the shallow aquifer is very thin around the periphery (i.e. along the foothills of the Oquirrhs) the transmissivities in this area are low.

As is generally the case throughout the West Jordan Valley, Kennecott hydrogeologic data also indicate that in the study area, water in the shallow unconfined aquifer generally contains more dissolved solids than does water in the principal aquifer. Reasons for this may be: (1) solution of minerals as water from the principal aquifer moves up through the confining bed into the shallow unconfined aquifer, (2) where the water table is close to the land surface evapotranspiration occurs, (3) irrigation water, canal water, and Kennecott surface water seepages, and (4) contamination from common salt used on roads. Published values for dissolved solids content of water from the shallow unconfined aquifer are presented in Appendix D. Values range from 24,300 mg/l (TDS) to 140 mg/l and average 2700 mg/l. Site specific shallow water quality data are presented in Table B-2, Appendix B.

Existing well log data and shallow and deep water quality data indicate strongly that the shallow unconfined aquifer is separated hydraulically from the underlying deep confined aquifer by a confining unit(s). Better definition of the lateral and vertical extent of this unit will be possible with additional hydrogeologic data obtained during future monitor well drilling.

Perched Aquifers

Perched aquifers are not well defined. The key perched aquifer in the study area is located between Herriman and Riverton (Figure 13). The perched aquifers are generally only a few tens of feet thick and at best are used to supply water to a few stock wells. The presence of perched aquifers near the Kennecott facilities and operations is not documented in the literature. However, shallow perched zones created by seepage from Kennecott's reservoir, leach dumps and evaporation ponds may be present. Hydrogeologic data from future monitor well drilling in this area will determine if such perched zones exist locally.

Deep (Principal) Aquifer

The deep principal aquifer in the study area has been mapped and defined by Marine, I. W. (1960) and Hely and others (1971). The deep aquifer characteristics and a potentiometric map are summarized in Figures 10, 11, 13, 14 and 15, respectively. Based on the 1958 potentiometric map completed by Marine, I. W. (1960), the 1969 potentiometric map completed by Hely and others (1971) and the water level elevation data collected by Kennecott in 1983 for this report, the potentiometric surface in the study area has remained fairly stable.

Recharge to the deep aquifer in the study area south of Magna and north of the Traverse Mountains is from recharge in the valley fill and seepage from bedrock in the Oquirrh Mountains. Subsurface outflow enters the valley fill as seepage directly from bedrock or as underflow in the channel fill at the canyon mouths. Based on U.S.G.S. estimates, an average value for transmissivity (T) of 500 ft^2/day, a hydraulic gradient (I) of .04, a flow path (L) of 135,000 feet, an average value of recharge from bedrock has been estimated at:

$$Q = TIL$$
$$Q = 2.7 \times 10^6 \text{ ft}^3\text{/day or } 106{,}000 \text{ acre ft/yr or}$$
$$3.5 \times 10^{10} \text{ gallons/yr}$$

? CHECK CHERRY? OK

Underflow through channel fill in canyons in the Oquirrhs has not been measured. However, the underflow through the Jordan Narrows into the Quaternary alluvial deposits which overlie the semiconsolidated sedimentary rocks of the Tertiary Age Salt Lake Formation is estimated to be around 2500 acre-feet/year.

In most of the valley central areas, ground water moves from deeper to shallower aquifers and from deeper to shallower zones in each aquifer. According to Hely and others (1971), the hydraulic head increases 1 foot with each increase of 50-150 feet in depth in the principal aquifer. The head increases 1 foot with each 8 feet down in the overlying confining bed.

As pointed out in the discussion on water level elevations near Kennecott's reservoir, the ground-water levels decrease with depth, probably due in part to recharge to the upper zone from reservoir seepage.

However, in the area near Kennecott's evaporation ponds, the deeper monitor wells (designated with the suffix "B") appear to have pressure heads nearly equal to or slightly greater (1-2 feet) than the overlying shallow aquifer. In particular, monitor wells P191A, B; P192A, B; P193A, B; P194 A, B; P196 A, B; and P197A, B illustrate this (Figure 18 and Table B-1, Appendix B).

why?

The lateral hydraulic gradient in the principal aquifer in the northern part of the valley is about .0002 and about .06 near the mountains in the southwestern part of the valley. Although the ground water velocities are highest near the mountains, the principal aquifer is also thinnest in these areas, which restricts the rate of water flowing out into the valley. A typical ground-water velocity in the Jordan Valley is around 2.6 ft/day, Hely and others (1971).

Ground water in the principal aquifer discharges into the shallow aquifer, then to seeps and springs into drainage ways (i.e. the Jordan River), by underflow to the Great Salt Lake, by pumped wells and flowing wells located primarily in the northern part of the valley and in the Jordan River flood plain and by seepage into open drainage ditches and tile drains in some low-lying farming and urban areas.

The transmissivity and storage coefficient of the principal aquifer in the Jordan Valley in the study area has been estimated to be around 1000 ft^2/day and .15, respectively. Although permeabilities of the principal aquifer are higher near the mountains, transmissivities are lower because the alluvial aquifer thins out towards the mountains.

The dissolved-solids content of waters in the principal aquifer moves laterally and vertically. The principal aquifer has very low dissolved-solids content in the east near Little Cottonwood and Big Cottonwood Creeks (100-250 mg/l) and very high dissolved-solids content near the Great Salt Lake (2000 mg/l) (Figure 10).

The dissolved-solids content of the principal aquifer increases at depth but decreases towards the middle and upper part of the aquifer (Figure 11). The middle part contains the least dissolved solids because travel through the middle part is the most direct route with the most rapid time. Water in the lower part moves through a longer path and acquires a greater dissolved-solids content, and receives some water from the underlying Tertiary age deposits. Water quality in Tertiary age deposits varies considerably and can improve or degrade the water quality in the principal aquifer. Published water quality data from the deep aquifer and Tertiary age deposits are included in Appendix D.

The ground water in the Jordan Valley is generally high in calcium, magnesium, sodium plus potassium, bicarbonate, sulfate and chloride. The water quality in the eastern part of the valley is generally low in dissolved solids because the recharge is through bedrock of crystalline and generally insoluble rocks. Lesser amounts of recharge from bedrock in the Oquirrh Mountains, poorer stream water quality discharging from the Oquirrh Mountains, recharge from irrigation of poor quality water from the Jordan River and contamination from mining operations contribute to the poorer water quality of the principal aquifer in the western part of the Jordan Valley. Dissolved-solids content of underflow through the Jordan Narrows ranges from 600 to 1000 mg/l, similar to the dissolved-solids content of water in the principal aquifer derived from recharge from bedrock in the adjoining area. Published dissolved solids values for creeks and wells representative of water quality from recharge through bedrock in the Oquirrhs are included in Appendix E.

According to Hely and others (1971), the general pattern of water quality in the southwestern part of the valley is modified locally because of differences in source and quality of recharge. Low dissolved solids content of water in parts of Sections 5 and 6, T.4S R.1W and Sections 31 and 32, T.3S R.1W is attributed to greater recharge from a more permeable bedrock area and recharge of water of good quality from the Provo Reservoir Canal.

According to Hely and others (1971), "In the area between Copperton and Lark, extending eastward toward the Jordan River near South Jordan, much of the ground water has been contaminated with drainage associated with mining activities and the use of mine drainage water for irrigation. Oxidation of sulfide minerals in the ore bodies near Bingham yields sulfates, sulfuric acid (which is neutralized by limestone in the Oquirrh Formation), metallic oxides, and other compounds, which are dissolved in percolating water that discharges into stream courses or recharges the ground-water reservoir. These reactions were occurring before mining began, thus there probably always was some contamination of ground and surface water near areas of sulfide minerals. Mining activity, however, particularly open-pit mining, probably increases the rate of oxidation by mechanically increasing the surface area exposed to the atmosphere. In addition, some contamination is caused by seepage of waste-dump leachates. Past disposal of liquid wastes in evaporating ponds in sec. 18, T. 3S., R. 1 W., has resulted in contamination of ground water in an area of several square miles west of South Jordan. Although these ponds have been abandoned, the effects are continuing." Kennecott has recognized this problem and has constructed cutoff trenches and lined evaporation ponds to minimize further impacts to the ground water in this area.

Water in Bingham Creek has been contaminated by seepage from acid leaching of tailings dumps near the mouth of Bingham Canyon. These waters are now being treated with lime and diverted to the newly constructed lined evaporation ponds.

The chemical quality of the water from Mascotte Tunnel (just north of Lark) probably is fairly representative of the present quality of recharge water from bedrock in the immediate vicinity. This tunnel drains active mine workings, and the dissolved-solids content of the water is approximately the same as that of water from wells near the Oquirrh Mountains just below the mine. U.S.G.S. published water quality data for the Mascotte Tunnel shows sulfate levels of around 867 mg/l and TDS levels of around 1310 mg/l (Table D-2, Appendix D).

Published water quality from wells and surface waters downgradient from the Bingham Mining District are presented in Appendix D.

According to Hely and others (1971), the principal aquifer contains little water between Copperton and Garfield and its chemical quality is generally unknown. The water is probably of the same chemical quality as that in the upper part of the deposits of Tertiary age. Analyses of water from wells in deposits of Tertiary age, indicate that the dissolved-solids content ranges from 488 to 647 mg/l. The U.S.G.S. (1971) reported average dissolved-solids content of water from wells in the principal aquifer in the Jordan Valley of around 700 mg/l.

Marine, I. W. (1960) presented a map with total dissolved solids content of springs and ground water in wells in the Jordan Valley sampled in the late 1950's. This map showed that: ground water near Herriman had TDS values of around 1100 ppm, ground water 2.5 miles south of Riverton had TDS values of around 1300 ppm, ground water 2 miles east of the Kennecott evaporation ponds had TDS values of around 2400 ppm, a seep just east of the Kennecott evaporation ponds had a TDS value of around 24,300 ppm, ground water 3 miles northeast of the evaporation ponds had TDS values of around 1640 ppm, ground water 2 miles north of the evaporation ponds had TDS values of around 1240 ppm, ground water 2 miles north of Copperton had TDS values of around 700 ppm, ground water near Kearns had TDS values of around 578 ppm and ground water near Midvale had TDS values of around 500 ppm. These 1950 data correspond well with current 1983-1984 water quality data.

Hely and others (1971) demonstrated that in general, the ground waters in the west southwest part of the Jordan Valley are high in TDS and sulfate.

WATER QUALITY - ROUND I RESULTS

A summary and listing of the water quality data included in this section are presented in Figures 22 through 26 and Table B-2, Appendix B. Not all of the laboratory water quality data were available at the time of report completion. All data from round 1 sampling will be checked again and some samples re-analyzed and included in the August 1984 draft environmental assessment report which will also include historical water quality evaluations. Figures 2 and 6 locate the sample sites.

In the discussions which follow, the term "elevated levels" refers to concentration levels in excess of background concentration levels based on current limited upgradient surface water and ground-water data.

SURFACE WATER

Springs and Streams

A total of 24 spring and stream samples and 5 samples from Kennecott's surface water facilities were collected for the round 1 surface water quality sampling effort (Tables B-1 and B-2, Appendix B). Four creeks and springs (S316, 318, 319 and 324) from sources upgradient of Kennecott's operations, seven sites along the Jordan River (S1, 2, 38, 166, 330, 313, 314), thirteen samples from creeks and streams downgradient of Kennecott's operations or in old mining areas such as in the Butterfield Creek and Midas drainages, (Figures 2 and 6) were sampled and analyzed.

Evaluation of water quality results from the surface water sample sites indicates the following:

Butterfield Creek Drainage

Waters from the Bingham mine portal (S21A) and U. S. mine portal (S53) are high in sulfate, TDS, iron, arsenic, cadmium, chromium, cobalt, manganese and zinc. The waters from the U. S. mine portal are of poorer quality with very high aluminum levels. Although zinc levels are quite high at both sites, lead levels are low and pH values are at or above 7.

Springs along the Butterfield Creek Drainage (S22B and S40) are of fairly good quality. Levels of TDS are around 1000 and 300 ppm and levels of sulfate around 200 and 30 ppm at sites S22B and S40, respectively.

Waters from above and below the Bingham mine portal, sites S21 and S21B, reflect waters both unaffected and affected by old mine workings, respectively. The TDS and sulfate levels above the portal are 800 and 250 ppm and below the portal are 1706 and 1000 ppm, respectively. Metal levels, such as magnesium, zinc, arsenic, manganese and iron are elevated in Butterfield Creek below the portal drainage.

Springs Upgradient (Unaffected by Kennecott Operations)

Barney's spring (S318) located approximately 1.5 miles northwest of Copperton, has a high TDS level (1653 ppm), Maple spring and Crystal spring (S319 and S316) approximately 5 miles northwest of Copperton, do not. Rose Canyon Creek, located approximately 3.5 miles southeast of Copperton, has very good quality water and a low TDS level of 503 ppm. Field conductivities on Maple and Crystal springs were measured at 675 and 335 umhos/cm, respectively. Values of pH were at or slightly above 7 at all three sites. Water from Barney's spring is elevated in chloride, manganese and gross alpha activity. Laboratory results on Maple and Crystal springs are not yet available.

Jordan River

The Jordan River samples at 9000 South (S-1), at 9400 South (S-330), 6400 South (S54), 4800 South (S313), 5800 South (S314) and 11500 South (S321), all sampled on 10/12/83, indicate that levels for TDS and sulfate average around 1000 ppm and 300 ppm, respectively. The Jordan River water at the Midas Creek inflow (S321) is of poorest quality with TDS and sulfate levels at 1686 and 542 ppm, respectively.

Miscellaneous Surface Water Sample Sites

Water quality in the Provo Reservoir Canal (S33) at 16150 South 2000 West is very good, with TDS and sulfate levels at 238 and 248 ppm, respectively.

Water quality in north Bingham Creek (S56) and Carrol Drain (S320) at 11800 South are only moderately high in TDS, sulfate and chloride. (Table B-2, Appendix B).

Spring samples (S343 and S344) were taken at sites approximately 9 miles northeast of Copperton, considerably downgradient of Kennecott's operations. Laboratory water quality data are not yet available. Field water quality tests indicate that these springs are fairly high in TDS with field conductivities measuring 1600 and 1700 umhos/cm. This is not surprising since these springs are located in a ground-water discharge area and they are near the Jordan River.

Kennecott Facilities

Surface water samples were collected from the Bingham reservoir (S200), the Kennecott leach fluid circuit (S236), Bingham Pit (S237), leach dumps (S-317) and the evaporation pond inflow (S238) (Tables B-1 and B-2, Appendix B).

The following summarizes the water quality data results:

Reservoir

The reservoir 500 m.g. waters (S200) are acidic (pH = 3.3) and are very high in copper, TDS, sulfate, aluminum, iron, manganese, nickel, zinc, radium and gross alpha and gross beta activities. Reservoir waters are moderately high in silver, arsenic, cadmium, chromium, nickel, lead and silica. Wells located immediately downstream and downgradient of the reservoir intercept poor quality waters with elevated concentrations of those same constituents found in the reservoir at high concentrations (Figures 22 through 26).

Evaporation Ponds

The evaporation pond inflow waters (untreated, S238) are neutral (pH=7.6) and are high in TDS, sulfate, manganese and gross alpha activity.

Slightly elevated levels of lead, molybdenum and nickel are also present.

Bingham Pit

Bingham Pit waters (S-237) are of fairly good quality (pH=7.4) with a TDS level around 2600 ppm. The waters are very high in magnesium, radium, gross alpha, and gross beta activities. The pit waters are only slightly elevated in copper and manganese.

Leach Fluid Circuit

Leach fluid waters (S236) are acidic (pH=2.4) and are very high in copper, TDS, sulfate, aluminum, iron, manganese, nickel, radium, gross alpha and gross beta and zinc. Levels of chloride, silver, arsenic and lead are slightly elevated.

Leach Dump

Waters from Kennecott's southernmost dump (S317) are acidic (pH=3.9), very high in copper, TDS, sulfate, chloride, aluminum, manganese and zinc. These waters are moderately high in iron, nickel and arsenic.

These waters are of better quality but of similar quality to that of the leach fluid. Waters in this dump area are collected in a pond and pumped back to the leach collection system.

GROUND WATER

The isoconcentration contour maps presented in Figures 22 through 26 illustrate the principal contaminant distributions in primarily the shallow (and possibly deep) aquifer near the reservoir and leach dumps, and only the deep aquifer to the east. These maps are very preliminary but illustrate that metal contamination is localized and that surrounding private wells to the south and east, although high in TDS and sulfate, do not show elevated concentrations of metals.

Alluvial (Shallow) Aquifer

Twenty shallow monitor wells and three shallow private wells were sampled as part of round 1 sampling (Tables B-1, B-2, Appendix B). Most of Kennecott's shallow monitor wells are located near the reservoir, along Bingham Creek, the evaporation ponds and along the leach dump area.

Water quality data from shallow wells K-84, K-85, K-120, K-100, K-26 near the reservoir indicate poor quality low pH waters very high in copper, TDS, sulfate, aluminum, iron, manganese, nickel, silica, radium, gross alpha and gross beta activities. Waters also show elevated levels of silver, arsenic, cadmium, chromium and lead, primarily as a result of seepage from the reservoir and in part, due to past discharges of acidic waters down Bingham Creek and possibly from canyon underflow.

Water quality data from shallower wells along Bingham Creek (P213A, P196A, P197A, P191A, P193A, P192A) indicate waters with elevated levels of TDS and sulfate. TDS and sulfate levels at well P213A, located approximately one mile east of the reservoir are around 98,000 and 40,000 ppm, respectively. These levels decline significantly at a distance of approximately 1.75 miles east of the reservoir (well P-196A), where levels of TDS and sulfate are only 1630 and 639 ppm, respectively.

The shallow ground waters along Bingham Creek are believed to have been affected by the infiltration of mine waters and acid leach solutions that were discharged along Bingham Creek and which infiltrated into the shallow aquifer. Lateral movement of shallow poor quality waters from reservoir seepage may contribute to this localized contamination.

Water quality data from shallow wells along the leach dumps (K67R, P220, K72, P234, P228, P225, P223) indicate low pH waters with some elevated levels of TDS, sulfate, chloride, magnesium, iron, manganese, lead, gross alpha, gross beta, zinc, nickel, cadmium and chromium.

These waters have been impacted by the infiltration of leach fluid along the dumps. Leach fluid is no longer allowed to freely flow along the dumps but is controlled by the east-side leach collection system (Figure 3).

Ground waters east and downgradient of the Lark tailings show elevated levels of similar constituents, especially manganese. The lateral and vertical distribution of the contaminants will be better defined following drilling and sampling of the new monitor wells.

Water quality data from two shallow private irrigation wells (W22 and W41A) located southeast of the leach dump area, approximately 2 and 2.5 miles west of Herriman, indicate that these wells intercept shallow ground water of fairly good quality. Field tests show conductivity and pH values for waters from wells W22 and W41A at 1000 umhos/cm and 6.7 and 7.1, respectively. Laboratory results indicate good quality water in well W41A, with metal concentrations, TDS and sulfate levels below Utah primary drinking water standards.

Perched Aquifers

Based on the data collected, delineation of perched aquifers in the study area is based solely on the work conducted by the U.S.G.S. (ref. Hely and others (1971), Figure 13). Water level data that will be obtained from the new monitor wells will be useful in delineating any perched aquifers near Kennecott's facilities.

Deep (Principal) Aquifer

Twenty-five Kennecott monitor wells and sixty-one private wells, open to the deeper aquifer, have been sampled in round 1 sampling. As previously discussed, most of the private wells used for irrigation can only be sampled when the owners are pumping them for irrigation purposes. Some of these wells are in key locations where no other monitor wells currently exist (i.e. wells W-11 and W-42, Figure 2). Samples from these wells can be obtained in the spring or summer of 1984, but only if the wells are being pumped.

Generally, throughout the study area and the valley, the water quality in the deeper wells is of better quality than that in the shallower wells. Kennecott monitor well water quality data from wells P190A, B; P191A, B; P192A, B; P193A, B; P194A, B; P197A, B; and P207A, B illustrate this.

In areas near the foothills of the Oquirrhs, near the reservoir and adjacent to the evaporation ponds, the water quality in some of the shallow and deep wells is nearly identical. This may be due to localized inter-aquifer flow between the shallow and deep aquifers. The isoconcentration contour maps (Figures 22-26) illustrate the areas and well sites where waters in the shallow and deeper zones are similar.

As discussed previously, the shallower wells along Bingham Creek and within 1.75 miles downgradient of the reservoir intercept low pH waters with elevated levels of copper, TDS, sulfate, magnesium, aluminum, iron, arsenic, cadmium, cobalt, manganese, nickel, lead, antimony and zinc (Table B-2, Appendix B, wells P213A, K26, K86). Deeper wells in this same area intercept water of slightly better quality but still poor (Table B-2, Appendix B, wells P213 B, C, K-88). However, there is significant improvement in the water quality of both the shallow and deep wells at a distance of approximately 1.5 to 1.75 miles east of the reservoir. The significantly better quality waters intercepted by shallow well P196A and deep wells K106 and K87 reflect this transition zone.

The deeper monitor wells surrounding the evaporation ponds are of significantly better quality than the shallower wells (Table B-2, Appendix B, wells P207B, P192B, P210b, P199). Well P198 located northwest of P199, is open from 510 to 520 feet and well P199 is open from 685 to 695 feet. Although the water quality in well P199 is fairly good, that in well P198 is poor. This appears to be due to the fact that P198 is shallower, closer to the evaporation ponds and may have shallow evaporation pond seepage waters flowing down along the outside of the well casing. Although such vertical seepage flow would generally be unlikely, in late 1983, this area was discovered to be a major discharge zone for lateral seepage from the evaporation ponds. Kennecott has completed a cutoff trench and is intercepting shallow lateral pond seepage.

Continued frequent monitoring of Kennecott monitor wells and private wells surrounding the evaporation ponds, particularly to the southeast, east and northeast, is ongoing.

Deeper monitor wells east of the leach dumps (wells K-70 and P211b) intercept good quality waters, with TDS values of 806 and 444 ppm, respectively. Well K-70 is only one mile east of the dumps and drilled to 313 feet and well P211b is nearly three miles east and open from 540 to 550 feet.

Waters of poor quality were intercepted by wells P202c and P208B, both of which monitor deeper zones southeast of the reservoir, from 560 to 600 feet and 420 to 433 feet, respectively. Water quality analysis from round 2 samples from these wells and new monitor well completions in this area will verify if the water quality data obtained from these wells, particularly from well P202C, are valid.

Until a second round of samples have been taken from well P202C, and possibly not until a new monitor well is drilled next to well P202C, the 1983 water quality data are suspect. Although this well was drilled in the late 1970's, this is the first time the well has been pumped and sampled. It was pumped at around 1.3 gpm for 4 hours, during which time a strong odor and blackish colored water were observed by the field crew (Appendix C).

Well P202C is located in a topographic depression (Figures 2 and 4) and could intercept a permeable channel which allows seepage flow from the large reservoir to flow southeast. However, it is unusual that the adjacent wells P202A and B, both of which are shallower, are dry and do not intercept any contaminant flow. It is also unusual that the water quality in wells P208A and B is so much better than that in well P202C. Wells P208A and B are located nearly one mile closer to the large reservoir and leach dumps.

The isoconcentration contour maps (Figures 22 through 26) illustrate that if these data from wells P202c and P208B are representative of the deeper aquifer water quality, it is possible that a highly permeable flow channel exists in this area which allows contaminant migration both laterally and vertically. Shallower wells P202a and P202b are dry.

Private wells located south and east of Kennecott's property are generally deep, from around 150 feet to 1218 feet with open zones generally from 180 to 400 feet. Most of these wells are used for irrigation, although the wells located just south and east of the evaporation ponds are used for drinking water (Table B-1, Appendix B).

The private wells located just south and east of the evaporation ponds (W309, W310, W311, W312) meet Utah primary drinking water standards (Table B-2, Appendix B). Levels of TDS, chloride and sulfate are elevated and the waters are hard but are within the primary drinking water standards.

Private wells located approximately one mile west of the Jordan River (W301, W302, and W306) do not meet Utah primary drinking water standards for TDS and sulfate or secondary standards for chloride. Slightly elevated lead levels above Utah primary drinking water standards are indicated. Wells W302 and W306 are irrigation wells and do meet the Utah agricultural standard for lead at 0.1 ppm. Well W301 water has a lead concentration slightly above 0.1, at 0.12. This well is used primarily for irrigation.

Unlike wells W300 and W305, located in the same vicinity, but with much better quality water, Wells W301, W302 and W306 are flowing wells completed at shallower depths (around 175 feet versus 295 feet). In fact, these wells have been flowing since completed, except for well W306, which began flowing approximately ten years ago. It is believed that the casing may have failed and opened to the same flow zone which W301 and W302 intercept.

Published water quality data obtained in the later 1950's from private wells in this vicinity (Appendix D, Table D-1, well W149; Table D-3, well (C-3-1) 2cab-1; Table D-4, wells W-11, W-149, C-3-1, (2adb-1, 15bda-2)) indicate that private wells in this area intercepted poor quality waters with elevated levels of the same constituents as currently found. In 1958 well W-11 intercepted ground waters with levels of TDS at 2390 ppm, sulfate at 1150 ppm and magnesium at 156 ppm.

The total dissolved solids and sulfate levels for wells located both north and south of the W300 series wells in Township 3 South Range 1 West were evidently fairly high, even back in the 1950's (Tables D-1 and D-4). TDS and sulfate levels generally ranged from around 500 to 1000 ppm and 100 to 600 ppm, respectively.

Laboratory water quality data from private wells W322, W131B, and W125 located south near Butterfield Creek indicate fairly high levels of TDS (1542 to 2370 ppm), sulfate levels of 330 to 499 ppm, elevated chloride levels (874 ppm at W125) and slightly elevated lead levels (0.12 ppm at W322). The aquifer in this area may be receiving poor quality recharge waters from the Oquirrhs. The southern part of the Oquirrhs was, as discussed previously, very heavily mined for lead, zinc and silver.

Private wells W31 and W189, located north and northeast of Kennecott's operations, intercept waters of very good quality (i.e. TDS values are 700 and 370 ppm, respectively). Well W31 is a Copperton City production well open from 149 to 1218 feet and well W189 belongs to Interstate Brick and is open from 350 to 637 feet.

Well W189 is only 3.4 miles east of the reservoir along Bingham Creek. The fact that this well and Kennecott's production well (K-109) are open to the deep aquifer and intercept good quality waters demonstrates that the deep aquifer in this area has not been degraded.

RECOMMENDATIONS

Introduction

The following recommendations are preliminary based on the limited available hydrogeologic data. Hydrogeologic data gaps in specific locations are evident. Recommended sites for drilling and new monitor well completions are based on these data gaps and potential problem areas.

A phased approach to drilling new monitor wells should enable thorough evaluation of hydrogeologic data in those areas where potential problems are believed to exist. Subsequent determination of strategic locations for completing remaining monitor wells based on this approach will allow for optimal monitoring of key problem areas.

Future Ground-Water and Surface Water Monitoring, Round 2

All monitor wells, private wells and surface water sites sampled during Round 1 shall be sampled in Round 2. Certain organic constituents sampled in Round 1 do not monitor contamination from Kennecott's operations and were analyzed strictly to determine approximate existing organic contaminant concentration levels (Appendix B, Table B-2). The expense and necessity of analyzing for these organics are not justified.

Table 1 lists the constituents sampled for Round 1 and those proposed for Round 2.

Additional Monitor Well Locations and Well Construction, Preliminary Recommendations for Phase I Drilling, in 1985

Proposed additional monitor well locations are shown on Figure 2. Shallow, deep and intermediate well completions are proposed for certain locations where hydrogeologic and water quality data indicate that vertical and lateral contaminant zoning may be occurring. A total of 15 location sites are indicated with possibly 27 well completions.

Six new monitor well location sites have been proposed along a North-South line east of Kennecott's waste leach dumps. These wells will be fairly shallow to monitor any leach fluid migration that has occurred in the upper shallow zone and water quality degradation from the Lark tailings. Three intermediate and two deep monitor wells may be completed in this well series to monitor the water quality in a vertical direction.

Five new monitor well location sites have been proposed off of Kennecott's property in an east-west line to the north of Kennecott's reservoir, Bingham Creek and the evaporation ponds. Exact locations are dependent on Kennecott's obtaining approval to complete monitor wells on private property. A total of eight monitor wells may be completed, five shallow and three of intermediate depth. The purposes for constructing and monitoring these wells are to evaluate the hydrogeology and water quality conditions to the north, off of Kennecott's property, and to monitor an area where there are not many private wells available for sampling.

Four new monitor well location sites are proposed for the area around and downgradient from the old evaporation ponds. A total of four shallow and four deep monitor wells would monitor the upper shallow aquifer and the deep principal aquifer. At least one and possibly two of these well location sites may be off of Kennecott's property in order to monitor any lateral contaminant movement offsite.

Proposed new monitor well locations and depths for Phase I drilling are subject to change as drilling commences. Field water quality testing (i.e. pH and conductivity) and lithologic changes observed during drilling will dictate final well depths and may indicate the need to shift other proposed well location sites to more strategic locations. Any major changes in locations would be discussed with Kennecott's consultants and the technical and advisory groups.

Specifications for additional monitor wells to be drilled in a Phase II drilling program cannot be determined until the data from the new Phase I monitor wells are evaluated. Hydrogeologic data, water level and water quality data from the Phase I wells and at least three rounds of comprehensive water quality data from existing monitor sites should dictate those areas and zones where existing or potential water quality problems do or could occur. These data shall be used to design and locate proposed new monitor wells for the eventual Phase II drilling.

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